The Yellowstone River Instream Reservation

DEC. 16, 1980 - DEC. 15, 1981

THIRD ANNUAL REPORT

Compiled By

Larry Peterman

Ecological Services Division
Department of Fish, Wildlife and Parks

THE YELLOWSTONE RIVER

INSTREAM

RESERVATION

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1420 East Sixth Avenue
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December, 1981

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INTRODUCTION

The Order of the Board of Natural Resources and Conservation establishing water reservations for the Yellowstone basin was signed on December 15, 1978. As a result of that Order, the Department of Fish, Wildlife and Parks was granted an instream reservation for the Yellowstone at Sidney of approximately 5.5 million acre-feet of water with varying amounts granted in upstream areas and tributaries.

The Department applied for instream reservations on many streams and tributaries where little, if any, flow data were available. In granting an instream reservation for those waters, the Board frequently granted a percentile flow rather than a specific amount of water in acre-feet or cfs. In such areas the Department was directed by the Board through condition 116 to develop and submit to the Board within 5 years of December 15, 1978, a plan to convert the minimum flow instream reservation quantities into cubic feet of water per second and acre-feet of water per month.

Condition 117 states that the reservant shall submit to the Board an annual progress report setting forth accomplishment toward completion of such work as outlined in condition 116, a schedule of anticipated progress and other information as may be required. This report is designed to fulfill the requirements of the third-year annual progress report.

The first annual progress report outlined a tentative plan for accomplishing the objectives in condition 116. The tentative plan was then reviewed, commented on and revised. The finalized plan was submitted in the second annual report and was approved by the Board on June 5, 1981. This report contains a verification of the Riggs' Method (Riggs 1968), on the upper Yellowstone as outlined in the second annual report. The testing and confirmation of the Riggs' methodology was done by Systems Technology, Inc., and presented verbally to the Board at the June 5, 1981, meeting.

Application of the Riggs' Method requires that monthly flow measurements for one year be taken on the streams to be analyzed. For those streams, a plan and tentative schedule is presented for collection of the necessary data.

The Verification of the Application of Riggs' Method to the Quantification of Percentile Flows in the Upper Yellowstone Basin

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June 25, 1981

RIGGS' METHOD VERIFICATION ON THE UPPER YELLOWSTONE BASIN

The purpose of this paper is to verify the applicability of the Riggs' Method to the estimation of percentile monthly flows in the upper Yellowstone basin. This is part of the work necessary to quantify the Department of Fish, Wildlife and Park's instream flow reservations in this area.

The application of the Riggs' Method is a two-step procedure. The first step converts a single field measurement of flow to an estimate of the mean flow for that month. This is not an estimate of the long-term mean monthly flow, only an estimate of the mean monthly flow for the month in which the field measurement was taken. This estimate is arrived at by comparison with a gaged stream in the area. Specifically,

$$\frac{Q_M(U)}{Q_C(U)} = \frac{Q_M(U)}{Q_C(G)}$$

where $Q_M(U)$ and $Q_M(G)$ are the mean monthly flows for the ungaged and gaged streams respectively, and $Q_C(U)$ and $Q_C(G)$ are the concurrent flows on the day of measurement at the ungaged and gaged streams respectively.

To verify this part of the Riggs' Method, estimated mean monthly flows for a number of streams with continuous gaged record were compared with the actual recorded mean monthly flow. We did this procedure for five different streams using years with high flows and years with low flows. The results of these calculations are in Tables 1 - 10. As an example the estimates for Big Creek using the Yellowstone River at Corwin Springs

as the gaged station are in Table 1. In October of 1974 the mean monthly flow was 1521 cfs for the Yellowstone and on a particular day, October 15, the flow was 1490 cfs. The corresponding concurrent flow for Big Creek on the 15th of October was 33 cfs. Thus, the Riggs' Method estimates the mean monthly flow for Big Creek to be:

$$Q_M(U) = Q_D(U) \times \frac{Q_M(G)}{Q_D(G)} = 33 \times \frac{1521}{1490} = 33.7 \text{ cfs}$$

The actual October mean flow on Big Creek was 33.8 cfs, so the estimate has negligible error in this case.

As Tables 1 and 2 show, mean monthly flows for Big Creek are generally estimated well by this method except for May when there was a difference in the peak runoff behavior of the two streams. Good agreement was also found for Rosebud Creek compared to the Stillwater River (Tables 3 and 4), Willow Creek compared to Red Lodge Creek (Table 6), and Sweetgrass Creek compared to the Boulder River (Tables 9 and 10). Problems occurred when Willow Creek was compared to the Stillwater River (Table 5) and when Butcher Creek was compared to the Stillwater River (Table 7). The important point here is to choose an appropriate comparison stream. Since there is no flow data available to make this comparison other than the few individual measured flows, a careful study of basin characteristics such as elevation, precipitation and irrigated acreage must be made before choosing a comparison station.

Riggs' second step was to estimate a long-term mean annual flow from the sum of the estimated mean monthly flows determined via step one. This sum is, of course, an estimate of the mean annual flow for the year in which the concurrent flow measurements were made. An estimate of the long-term mean annual flow is not the desired result for the instream flow reservations. The desired result is an estimate of a mean monthly per-

centile flow, such as the 90th percentile flow. To achieve this result, the principle of the Riggs' second step is maintain however the actual procedure is modified.

As a first attempt, percentile flows were calculated using what will be called in this paper the "short method." This method simply uses the ratios of the concurrent flows on the day of measurement to proportion the percentile flow for that month on the gaged stream. Mathematically, this is given by:

$$\frac{Q_P(U)}{Q_C(U)} = \frac{Q_P(G)}{Q_C(G)}$$

where $Q_P(U)$ and $Q_P(G)$ are the percentile flows (say the 90th percentile flow) for the ungaged and gaged streams respectively, and $Q_C(U)$ and $Q_C(G)$ are the concurrent flows on the day of measurement at the ungaged and gaged streams respectively.

In order to test the validity of this method, streams were chosen with fairly well established percentile flows (greater than 10 years of record) and the percentile flow calcuations were performed for the various months. In particular, Sweetgrass Creek was tested with the Boulder River as the comparison station, using the 90% flow for two years, 1958 and 1957 (Tables 11 and 12), and Brackett Creek was tested using the Shields River at Wilsall for comparison. This short method gave rather high percent errors, over 70% for many months.

In hopes of improving the estimates of percentile flows, a method similar in principle to Riggs' second step was tried. In following discussions, this method will be referred to as the "complete method." This method is similar to the procedure used by Riggs to convert mean annual

flows to long-term means. Since the objective is to estimate monthly percentile flows, linear regression was used to find the "best fit" line for a graph of monthly percentile flows versus the mean monthly flow for the month of concurrent flow measurement for a number of gaged streams. Graphs displaying this analysis are presented in Figures 1 - 12. These figures show the "best fit" lines for the 50th and 90th percentile flows for each month in water year 1957.

In order to derive a percentile flow for an ungaged stream, one first determines the mean monthly flow for the month of measurement on the ungaged stream using the first step of the Riggs method. For example, the estimate for Sweetgrass Creek using the Boulder River as a comparison stream for October 1957 is a mean monthly flow of 21 cfs. This happens to be a very accurate estimate. Then using Figure 1, 21 cfs is found on the X axis and using the 90% line converted to 19.3 cfs on the Y axis. This estimate of the 90% flow is low by 8%, again a very good estimate.

Tables 15 and 16 summarize the results of the complete method for Sweetgrass Creek and Brackett Creek. For the fall and winter months, the complete method gives comparable percent errors to the short method. However, for the summer months the complete method gives markedly improved estimates on Sweetgrass Creek, often reducing the short method's percent errors by one half. The complete method does not improve the accuracy of the estimate on Brackett Creek in either summer or winter; in fact, the errors tend to be slightly higher for the complete method (see Tables 14 and 16). This is because the Shields River at Wilsall is apparently a very good comparison stream for Brackett Creek. In cases where a very good comparison between two streams can be expected, the short method may be quite accurate. However, it is difficult to determine

if two streams are really comparable without flow data on both streams. Since basin characteristics are the only means of comparison, it is safer to use the regression line than to hope that a single comparison stream is indeed the best estimator of percentile flows. Safe in this context means that gross misestimates are less likely.

It should be noted that the regression lines in Figures 1 - 12 are determined from four arbitrarily selected streams. With a careful study of basin characteristics for all gaged streams in the upper Yellowstone basin, and omission of hydrologically different streams, better regression lines than these can be determined.

PLAN AND SCHEDULE FOR DATA COLLECTION

Table 17 shows a list of the streams grouped according to the amount of continuous, consecutive streamflow record available. Those streams listed in column A should not need a collection program for flow data. Sufficient data presently exists to determine the desired flows for these streams. This determination will be made during the next report period.

For Hanging Woman, Otter, Pumpkin, Rosebud (Yellowstone) and Big creeks, only three more years of record are required. Unfortunately, the Big Creek station was discontinued during this report period. If funding permits, this station should be reactivated. The remainder are currently active stations and should be continued. No other data collection should be required and the necessary analysis can be performed when the additional data becomes available. In addition, the DFWP established a gage station at the mouth of the Shields River in 1978. This station will be continued until 10 years of record are obtained.

Only a small number of the remaining streams in columns B and C of Table 17 would probably have sufficient data to yield acceptable results from modeling techniques without the collection of additional data. These streams should be determined within the next report period and have the proper analysis done. For the remainder of the streams, the approved hydrologic modeling technique is the method developed by H.C. Riggs (see second Annual Yellowstone Instream Reservation Report - Peterman, 1981). This method would require the collection of concurrent flow data once monthly for a year from both the streams to be analyzed and the streams to be used as the nearby, long-term gaging stations. This will not require the installation of a USGS type continuous recording station. The needed flow data can be obtained from instantaneous flow measurements taken semi-monthly during the high flow period and monthly during the remainder of the year. For those streams where some data exists, collection may only be necessary in those months with no or too little data.

We have tentatively scheduled the streamflow data collection program for those streams with insufficient record to begin in March 1982. Streamflow data will be collected on 14 streams per year. The data collection program should be completed within three years. Flow reservation quantities will be calculated for individual streams in the year following completion of their data collection phase. This schedule is tentative and may be subject to revision depending on manpower availability and funding.

Because of the close proximity, and general similarity of basin characteristics for the streams in the upper Yellowstone basin, few if any, should require any more of an intense data collection program than that prescribed by the Riggs' method. However, spring-fed streams such as Armstrong, Nelson, McDonald

and Emigrant Spring Creek may not be amenable to the Riggs' method. A more intensive data collection program may be required (e.g., operating a gaging station for a year or two, or making frequent measurements for several years). The data collection program for these spring creeks will be directed toward the use of one of the other hydrologic modeling techniques.

UPDATE OF LEGAL PROCEEDINGS RELATED TO YELLOWSTONE RIVER WATER RESERVATION

This section provides further information on legal and administrative occurrences since December 15, 1980. From the December 1980 report, the Utah International v. DF & G, et al. case is the only case not settled or otherwise disposed of at this time. The Utah case was stayed until a determination of a separate district court case between Utah International, Inc. and Intake Water Co. That separate case revolves on the issue of whose filing for a water right permit in the Powder River has first priority. No action has been reported to the appropriate district court during this report period. During this reporting period, the Board, of its own motion or otherwise, took no action directly related to the Department of Fish, Wildlife and Parks' reservation in the Yellowstone River. No other legal or administrative activities took place. This section was prepared by F. Woodside Wright, Department Attorney for the Department of Fish, Wildlife and Parks.

Table 1. Mean Monthly Flow Estimates For Big Creek Near Emigrant Using Yellowstone River at Corwin Springs as Comparison - Water Year 1975.

	Yellowstone at Corwin Springs (USGS # 6-1915)		Big Creek Near Emigrant (USGS # 6-1918)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	1,490	1,521	33	33.8	45	33.7	0%
Nov.	1,140	1,160	35	34.1	34	35.6	+4%
Dec.	975	962	30	27.5	35	29.6	+8%
Jan.	750	765	23	24.3	31	23.4	-3%
Feb.	707	721	23	23.2	31	23.5	+1%
March	953	948	23	23.1	41	22.9	-1%
Apr.	1,070	1,044	25	25.7	41	24.4	-5%
May	2,590	2,575	154	91.2	28	153.0	+68%
June	11,800	11,610	325	285.0	41	255.0	-11%
July	12,600	12,470	286	292.0	43	283.0	-3%
Aug.	4,210	4,371	60	59.1	74	62.3	+5%
Sep.	2,280	2,327	31	34.2	68	31.6	-7%

Table 2. Mean Monthly Flow Estimates For Big Creek Rigg's Flows Using Yellowstone River at Corwin Springs as Comparison - Water Year 1977.

	Yellowstone at Corwin Springs (USGS # 6-1915)		Big Creek (USGS # 6-1918)				
	On 15th	Mean Monthly	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	1,690	1,664	34	34.2	49.0	33.5	-2%
Nov.	1,090	1,164	31	30.0	38.8	32.0	+7%
Dec.	975	926	27	26.6	34.8	25.6	-4%
Jan.	720	748	23	23.9	31.3	23.9	0%
Feb.	752	767	24	24.0	32.0	24.5	+2%
March	828	841	24	23.8	35.0	24.4	+2%
April	1,360	1,719	42	50.1	34.0	53.1	+6%
May	5,400	3,835	127	86.9	44.0	90.2	+4%
June	6,460	6,788	171	149.0	45.0	179.0	+21%
July	2,580	2,723	41	44.2	62.0	43.3	-2%
Aug.	1,600	1,711	26	27.1	63.0	27.8	+3%
Sept.	1,290	1,381	28	25.7	54.0	30.0	+17%

Table 3. Mean Monthly Flow Estimates For Rosebud Creek Near Absarokee Compared to Stillwater River Near Absarokee - Water Year 1961.

	Stillwater River (USGS # 6-2050)		Rosebud Near Absarokee (USGS # 6-2045)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	381	345	175	161.0	0.47	158.0	-2%
Nov.	345	330	165	157.0	0.48	156.0	+1%
Dec.	250	286	150	153.0	0.61	172.0	+12%
Jan.	275	245	153	136.0	0.56	137.0	+1%
Feb.	254	255	161	152.0	0.60	162.0	+6%
March	220	207	134	129.0	0.62	126.0	-2%
April	167	144	92	65.7	0.46	79.3	+21%
May	292	920	81	305.0	0.33	255.0	-16%
June	2,100	2,528	524	731.0	0.29	630.0	-14%
July	756	803	384	397.0	0.49	408.0	+3%
Aug.	609	471	303	246.0	0.52	234.0	-5%
Sept.	812	765	416	411.0	0.54	392.0	-5%

Table 4. Mean Monthly Flow Estimates For Rosebud Creek Near Absarokee Compared to Stillwater River Near Absarokee - Water Year 1962.

	Stillwater River (USGS # 6-2050)		Rosebud Near Absarokee (USGS # 6-2045)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	670	670	318	320	0.48	318	-1%
Nov.	602	541	297	274	0.51	267	-3%
Dec.	450	430	209	208	0.48	200	-4%
Jan.	300	337	175	167	0.50	197	+18%
Feb.	358	401	205	195	0.49	230	+18%
March	290	311	136	176	0.57	145	-17%
April	348	563	210	270	0.48	340	+26%
May	1,340	1,236	574	471	0.38	529	+12%
June	5,000	5,995	1,480	1,285	0.32	1,181	-8%
July	2,810	2,527	1,380	1,076	0.43	1,241	+15%
Aug.	1,050	1,179	554	614	0.52	622	+1%
Sept.	852	777	380	357	0.46	347	-3%

Table 5. Mean Monthly Flow Estimates For Willow Creek Near Boyd Compared to Stillwater River Near Absarokee - Water Year 1961.

	Stillwater River (USGS # 6-2050)		Willow Creek (USGS # 6-2115)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	381	345	18.0	16.30	0.05	16.30	0%
Nov.	345	330					
Dec.	250	286					
Jan.	273	245					
Feb.	254	255					
March	220	207					
April	167	144	3.3	6.29	0.04	2.85	-55%
May	292	920	19.0	7.43	0.01	59.90	+706%
June	2,100	2,528	1.6	2.05	0.0008	1.93	-6%
July	756	803	7.6	8.49	0.01	8.07	-5%
Aug.	609	471	18.0	11.80	0.03	13.90	+18%
Sept.	812	765	27.0	36.30	0.05	25.40	-30%

Table 6. Mean Monthly Flow Estimates for Willow Creek Near Boyd Compared to Red Lodge Creek - Water Year 1965.

	Red Lodge Creek (USGS # 6-2110)		Willow Creek Near Boyd (USGS # 6-2115)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	28	38.9	22	26.1	1.49	30.5	+17%
Nov.							
Dec.							
Jan.							
Feb.							
March							
April	67	70.9	44	52.0	1.36	46.0	-10%
May	89	92.0	35	31.9	2.88	36.2	+13%
June	153	151.0	21	30.2	5.00	20.7	-31%
July	88	90.5	63	60.0	1.51	64.8	+8%
Aug.	40	53.2	46	56.4	0.94	61.2	+8%
Sept.	83	82.9	70	64.3	1.29	69.9	+9%

Table 7. Mean Monthly Flow Estimates For Butcher Creek Compared to Stillwater River Near Absarokee - Water Year 1961.

	Stillwater River Near Absarokee (USGS # 6-2050)		Butcher Creek Near Absarokee (USGS # 6-2043)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	381	345	24.0	25.20	14	21.70	-14%
Nov.	345	330	9.2	10.90	30	8.80	-19%
Dec.	250	286	5.0	4.11	72	5.72	+39%
Jan.	273	245	6.0	2.63	93	5.38	+105%
Feb.	254	255	3.4	3.24	79	3.41	+5%
March	220	207	2.0	4.25	49	1.88	-56%
April	167	144	8.0	8.58	17	6.90	-20%
May	292	920	16.0	21.60	43	50.41	+133%
June	2,100	2,528	28.0	38.50	66	33.70	-12%
July	756	803	44.0	49.20	16	46.70	-5%
Aug.	609	471	63.0	52.20	9	48.70	-7%
Sept.	812	764	49.0	53.20	14	46.10	-13%

Table 8. Mean Monthly Flow Estimates For Butcher Creek Near Absarokee Using Red Lodge Creek as Comparison Station - Water Year 1961.

	Red Lodge Creek (USGS # 6-2110)		Butcher Creek (USGS # 6-2043)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	37	26.5	24.0	25.20	1.05	17.0	-32%
Nov.							
Dec.							
Jan.							
Feb.							
March							
April	13	12.7	8.0	8.58	1.48	7.8	-9%
May	12	23.7	16.0	21.60	1.10	32.0	+46%
June	22	26.8	28.0	38.50	0.70	34.0	-11%
July	28	29.8	44.0	49.20	0.61	47.0	-5%
Aug.	35	27.6	63.0	52.20	0.53	50.0	-5%
Sept.	64	52.9	49.0	53.20	0.99	40.5	-24%

Table 9. Mean Monthly Flow Estimates For Sweet Grass Creek Above Melville Using Boulder River at Big Timber as Comparison - Water Year 1965.

	Boulder River (USGS # 6-2000)		Sweet Grass Creek (USGS # 6-2005)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	141	142	33.0	29.3	0.21	33.20	+13%
Nov.	135	185	16.0	17.7	0.11	21.90	+24%
Dec.	100	168	10.0	18.1	0.11	16.80	-7%
Jan.	174	158	23.0	16.7	0.11	20.90	+25%
Feb.	150	156	8.0	12.8	0.08	8.32	-35%
March	125	117	11.0	11.4	0.10	10.30	-10%
April	133	201	18.0	23.0	0.11	27.20	+18%
May	1,000	957	99.0	127.0	0.13	94.70	-25%
June	3,090	3,656	279.0	525.0	0.14	330.00	-37%
July	2,020	2,252	248.0	277.0	0.12	276.00	0%
Aug.	361	508	87.0	119.0	0.23	122.00	+3%
Sept.	558	433	198.0	105.0	0.24	153.00	+46%

Table 10. Mean Monthly Flow Estimates For Sweet Grass Creek Using Boulder River at Big Timber as Comparison - Water Year 1961.

	Boulder River (USGS # 6-2000)		Sweet Grass Creek (USGS # 6-2005)				
	On 15th (cfs)	Mean Monthly (cfs)	On 15th	Mean Monthly	Ratio of Means	Rigg's Means	% Error
Oct.	104	124.0	28.0	26.7	4.6	31.80	+19%
Nov.	158	154.0	21.0	19.0	8.1	20.50	+8%
Dec.	108	144.0	5.0	11.1	13.0	6.70	-40%
Jan.	135	120.0	10.0	8.55	14.0	8.90	+4%
Feb.	110	113.0	6.0	6.64	17.0	7.70	+16%
March	106	107.0	7.5	5.74	18.0	7.57	+32%
April	55	66.7	8.0	8.93	7.5	9.70	+9%
May	206	852.0	18.0	159.00	5.3	74.00	-53%
June	2,010	2,347.0	222.0	298.00	7.9	259.00	-13%
July	170	206.0	64.0	69.90	3.0	78.00	+11%
Aug.	24	21.9	35.0	34.30	0.6	31.90	-7%
Sept.	218	230.0	25.0	27.20	8.5	26.40	-3%

Table 11. Mean Monthly Flow Estimates For Sweet Grass Creek Compared to Boulder River - Water Year 1958 (A Low Year) - Short Method, 14 Years of Record 1956 - 1969.

	Boulder On 15th	Sweet Grass On 15th	Ratio	90% Boulder	90% Sweet Grass	90% Est. Sweet Grass	% Error
Oct.	219	27	0.120	125	21	15.0	-27%
Nov.	209	21	0.100	156	16	15.7	-2%
Dec.	155	19	0.120	142	10	17.4	+74%
Jan.	130	15	0.120	124	8	14.3	+79%
Feb.	110	13	0.120	109	7	12.9	+84%
March	135	10	0.074	111	7	8.2	+17%
April	153	25	0.160	102	10	16.7	+67%
May	1,030	236	0.230	706	92	160.0	+76%
June	1,960	247	0.130	2,036	266	257.0	-4%
July	478	120	0.250	418	102	104.0	+3%
Aug.	95	59	0.620	52	45	32.0	-28%
Sept.	80	39	0.490	91	28	44.0	+58%

Table 12. Mean Monthly Flow Estimates For Sweet Grass Creek Compared to Boulder River - Water Year 1957 (A High Year) - Short Method, 14 Years of Record 1956 - 1969.

	Boulder On 15th	Sweet Grass On 15th	Ratio	90% Boulder	90% Sweet Grass	90% Est. Sweet Grass	% Error
Oct.	126	20.0	0.160	125	21	20.0	-6%
Nov.	170	11.0	0.065	156	16	10.0	-37%
Dec.	165	7.0	0.042	142	10	6.0	-40%
Jan.	135	5.0	0.037	124	8	4.6	-43%
Feb.	115	7.0	0.061	109	7	6.6	-5%
March	110	7.0	0.064	111	7	7.1	+1%
April	126	9.0	0.071	102	10	7.3	-27%
May	1,970	423.0	0.210	706	92	150.0	+65%
June	2,570	190.0	0.074	2,036	266	150.0	-43%
July	1,570	194.0	0.120	418	102	52.0	-49%
Aug.	184	55.0	0.300	52	45	16.0	-65%
Sept.	294	34.0	0.120	91	28[1/]	10.5	-62%

1/ Full period of record

Table 13. Mean Monthly Flow Estimates For Brackett Creek Compared to Shields River Near Wilsall - Water Year 1953 (A High Year) - Short Method, 22 Years of Record 1936 - 1957.

	Shields On 15th	Brackett On 15th	Ratio	50% Shields	50% Brackett	50% Est. Brackett	% Error
Oct.	13	10.00	.770	16	10	12.30	+23%
Nov.	14	7.90	.560	16	8	9.00	+12%
Dec.	12	2.00	.170	13	5	2.20	-56%
Jan.	9	.60	.067	10	6	.67	+11%
Feb.	11	3.00	.270	10	6	2.70	-55%
March	11	2.50	.230	12	9	2.70	-70%
April	14	9.50	.680	49	42	33.00	-20%
May	68	52.00	.760	210	96	160.00	+70%
June	770	221.00	.290	211	72	61.00	-16%
July	117	62.00	.530	56	26	30.00	+14%
Aug.	28	16.00	.570	20	10	11.00	+14%
Sept.	14	9.80	.700	14	10	9.80	-7%

Table 14. Mean Monthly Flow Estimates For Brackett Creek Compared to Shields River - Water Year 1957 - Short Method, 22 Years of Record 1936 - 1957.

	Shields On 15th	Brackett On 15th	Ratio	50% Shields	50% Brackett	50% Est. Brackett	% Error
Oct.	8.6	8.1	.94	16	10	15.1	+51%
Nov.	11.0	7.0	.64	16	8	10.2	+27%
Dec.	9.6	5.5	.57	13	7	7.4	+5%
Jan.	10.0	5.8	.58	10	6	5.8	-3%
Feb.	7.5	5.4	.72	10	6	7.2	+20%
March	12.0	6.5	.54	12	9	6.5	-28%
April	17.0	14.0	.82	49	42	40.0	-4%
May	500.0	98.0	.20	210	96	41.0	-57%
June	81.0	46.0	.57	211	72	120.0	+66%
July	42.0	26.0	.62	56	26	35.0	+33%
Aug.	17.0	6.6	.39	20	10	7.8	-22%
Sept.	12.0	10.0	.83	14	10	11.7	+17%

Table 15. Mean Monthly Flow Estimates For Sweet Grass Creek Compared to Boulder River - Water Year 1957 - Complete Method.

	Ratio (From Table 12)	Boulder Mean Monthly Flow	Sweet Grass Est. Mean Monthly	Sweet Grass Est. 90% Flow	Sweet Grass Actual 90% Flow	% Error
Oct.	.160	130	21.00	19.30	21	-8%
Nov.	.065	182	11.80	9.50	17	-44%
Dec.	.042	156	6.50	4.80	11	-52%
Jan.	.037	129	4.77	4.90	9	-46%
Feb.	.061	116	7.08	4.25	8	-47%
March	.064	109	6.98	4.99	8	-38%
April	.071	133	9.40	9.20	10	-8%
May	.210	1,656	348.00	169.00	98	+72%
June	.074	4,003	296.00	157.00	246	-36%
July	.120	1,788	214.00	80.80	111	-27%
Aug.	.300	246	73.80	35.50	45	-22%
Sept.	.120	283	34.00	18.80	28	-33%

Table 16. Mean Monthly Flow Estimates For Brackett Creek Compared to Shields River - Water Year 1957 - Complete Method.

	Ratio (From Table 14)	Shields Mean Monthly	Brackett Mean Monthly	Brackett Est. Mean Monthly	Brackett Est. 50%	Brackett Actual 50%	% Error
Oct.	.94	9.32	7.57	8.80	12.00	10	+20%
Nov.	.64	10.50	7.26	6.70	12.50	8	+56%
Dec.	.57	10.20	6.00	5.80	11.30	7	+62%
Jan.	.58	9.29	5.61	5.40	9.17	6	+53%
Feb.	.72	8.21	6.20	5.91	8.16	6	+36%
March	.54	12.10	8.12	6.53	7.56	9	-16%
April	.82	29.50	18.60	24.20	34.40	42	-18%
May	.20	287.00	88.80	57.40	41.10	96	-57%
June	.57	264.00	57.40	150.00	130.00	72	+80%
July	.62	61.90	25.30	38.40	40.00	26	+53%
Aug.	.39	17.30	7.21	6.74	8.50	10	-15%
Sept.	.83	13.90	9.66	11.50	12.40	10	+24%

Table 17. Stream Grouping According to Available Flow Data

A Streams With 10 or More Years of Record	B Streams With Less Than 10 Years of Record	C Streams With No Streamflow Record
Willow Creek (no winter record)	Hanging Woman Creek	Clear Creek
Red Lodge Creek	Otter Creek	Dry Creek
Rock Creek	Pumpkin Creek	Castle Creek
Bluewater Creek	Rosebud Creek (Yellowstone)	Little Rocky Creek
W. Rosebud Creek	Butcher Creek	West Fishtail Creek
Sweet Grass Creek	Picket Pin Creek	East Fishtail Creek
Brackett Creek	W.F. Stillwater Creek	Bridger Creek
Clarks Fork Yellowstone	Mainstem Fishtail	L. Deer Creek
	E. Rosebud Creek	U. Deer Creek
	Cottonwood Creek	Mission Creek
	Rock Creek (Shields)	L. Mission Creek
	Tom Miner Creek	Smith Creek
	Rock Creek (Upper Yellowstone)	Flathead Creek
	Big Creek	Mol Heron Creek
	Fridley Creek	Cedar Creek
	Mill Creek	Six Mile Creek
	Shields River at mouth	Eight Mile Creek
	Bear Creek	Suce Creek
		Coke Creek
		Armstrong Spring Creek
		Nelson Spring Creek
		McDonald Spring Creek
		Emigrant Spring Creek
		Cinnabar Creek
		Trail Creek
		Billman Creek
		Fleshman Creek
		Sage Creek

Figure 1 PERCENTILE FLOW VERSUS MEAN FLOW FOR OCTOBER 1956

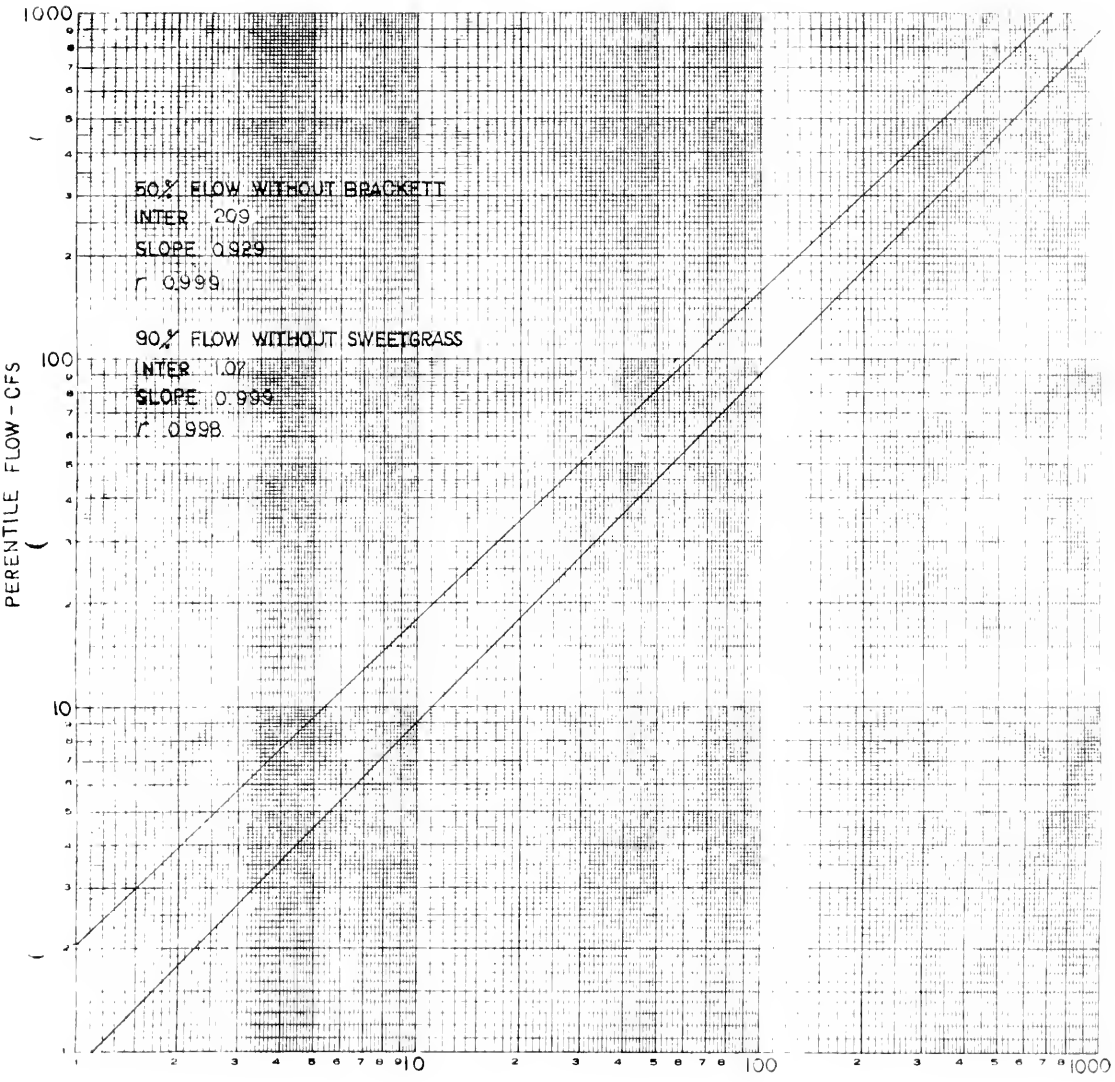


Figure 2 PERCENTILE FLOW VERSUS MEAN FLOW FOR NOVEMBER 1956

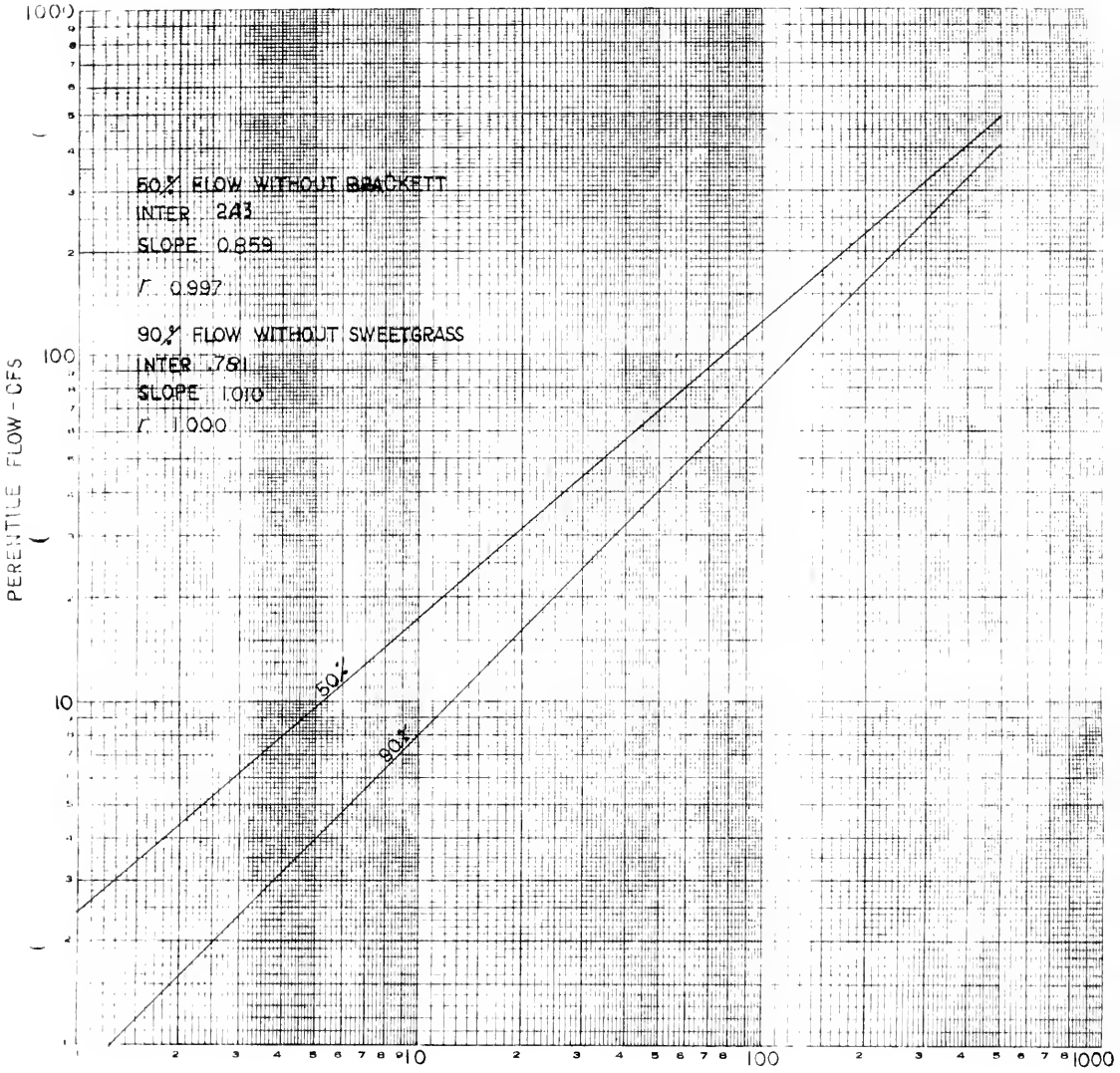


Figure 3 PERCENTILE FLOW VERSUS MEAN FLOW FOR DECEMBER 1956

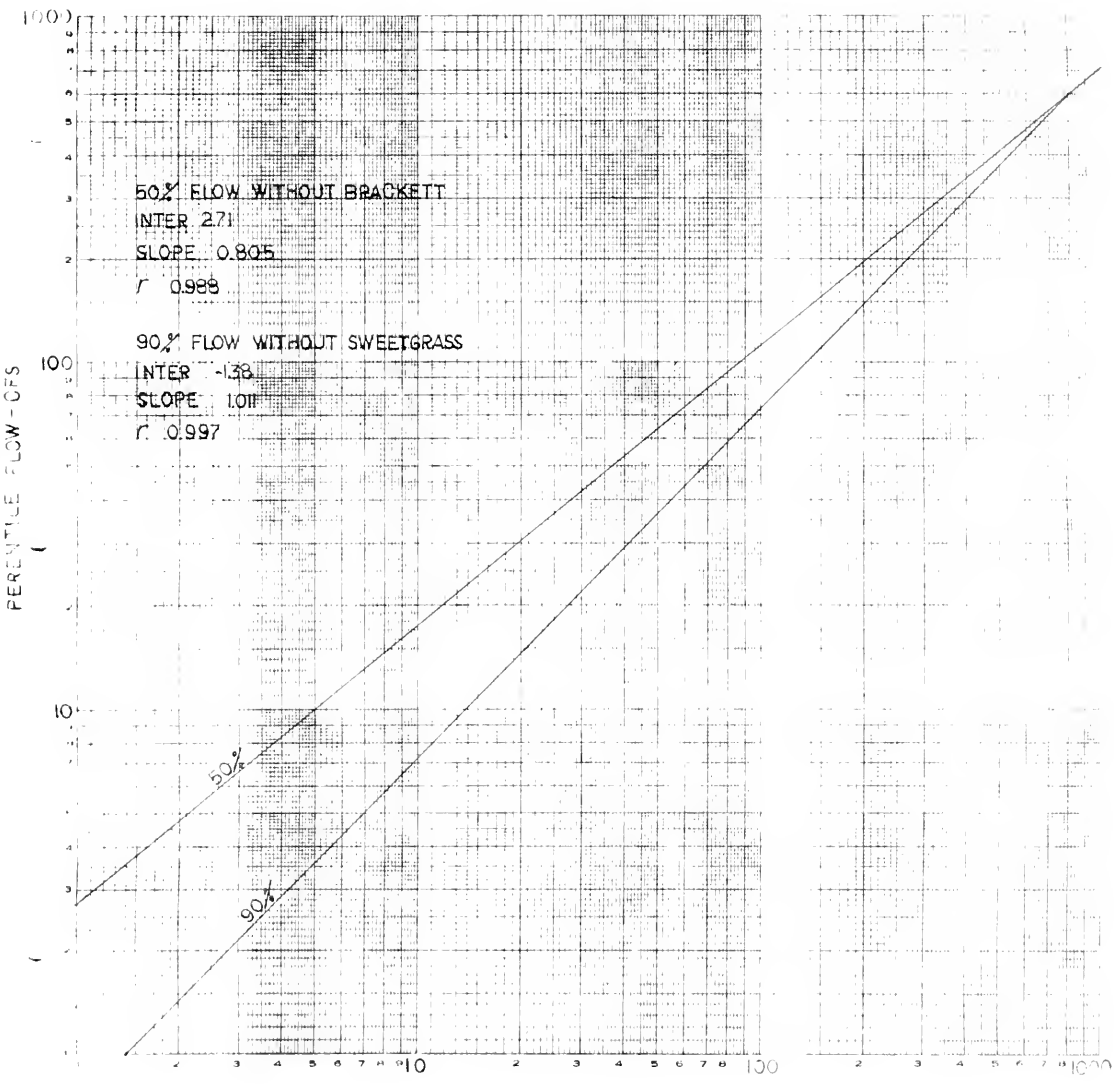


Figure 4 PERCENTILE FLOW VERSUS MEAN FLOW FOR JANUARY 1957

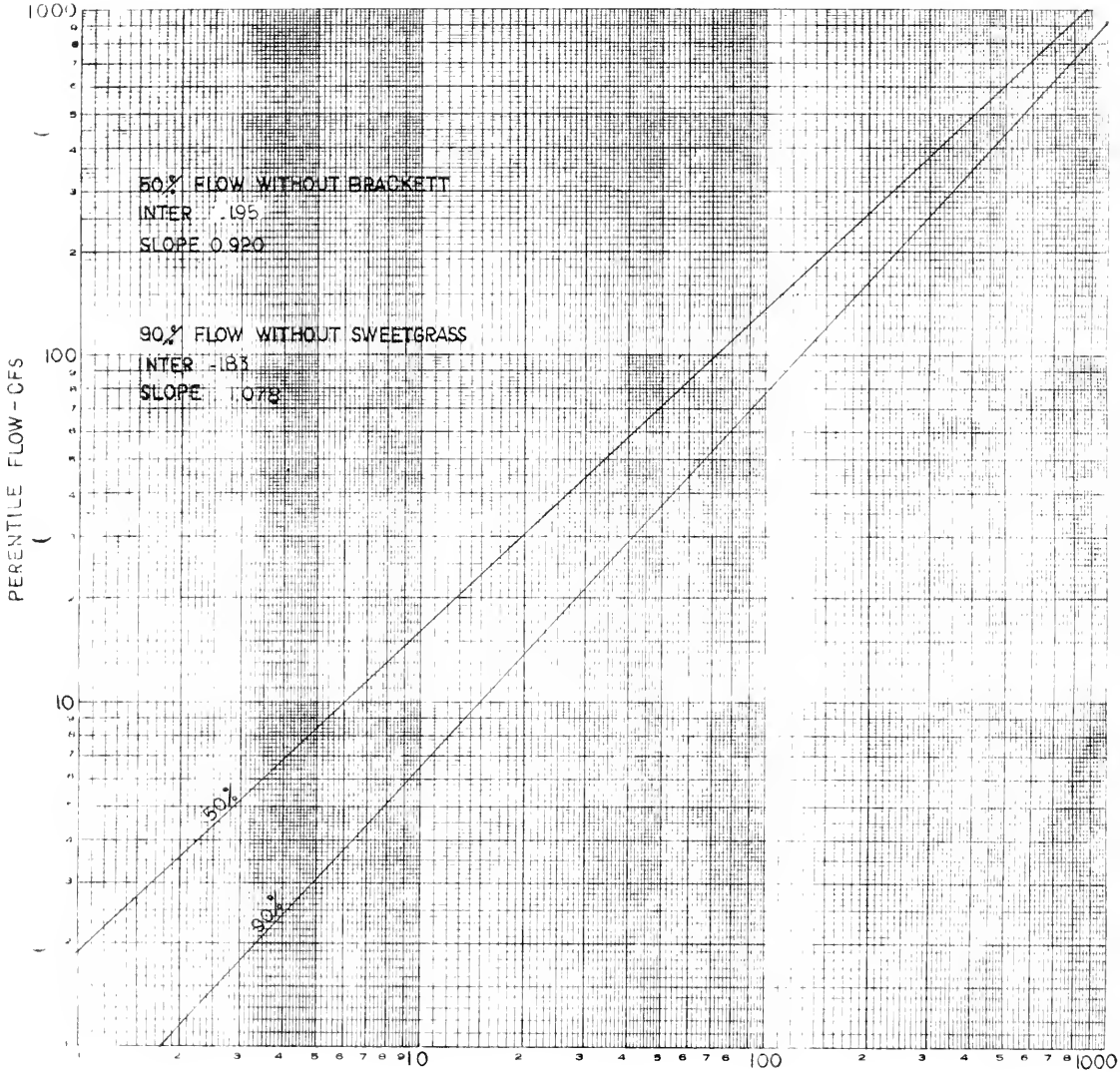


Figure 5 PERCENTILE FLOW VERSUS MEAN FLOW FOR FEBRUARY 1957

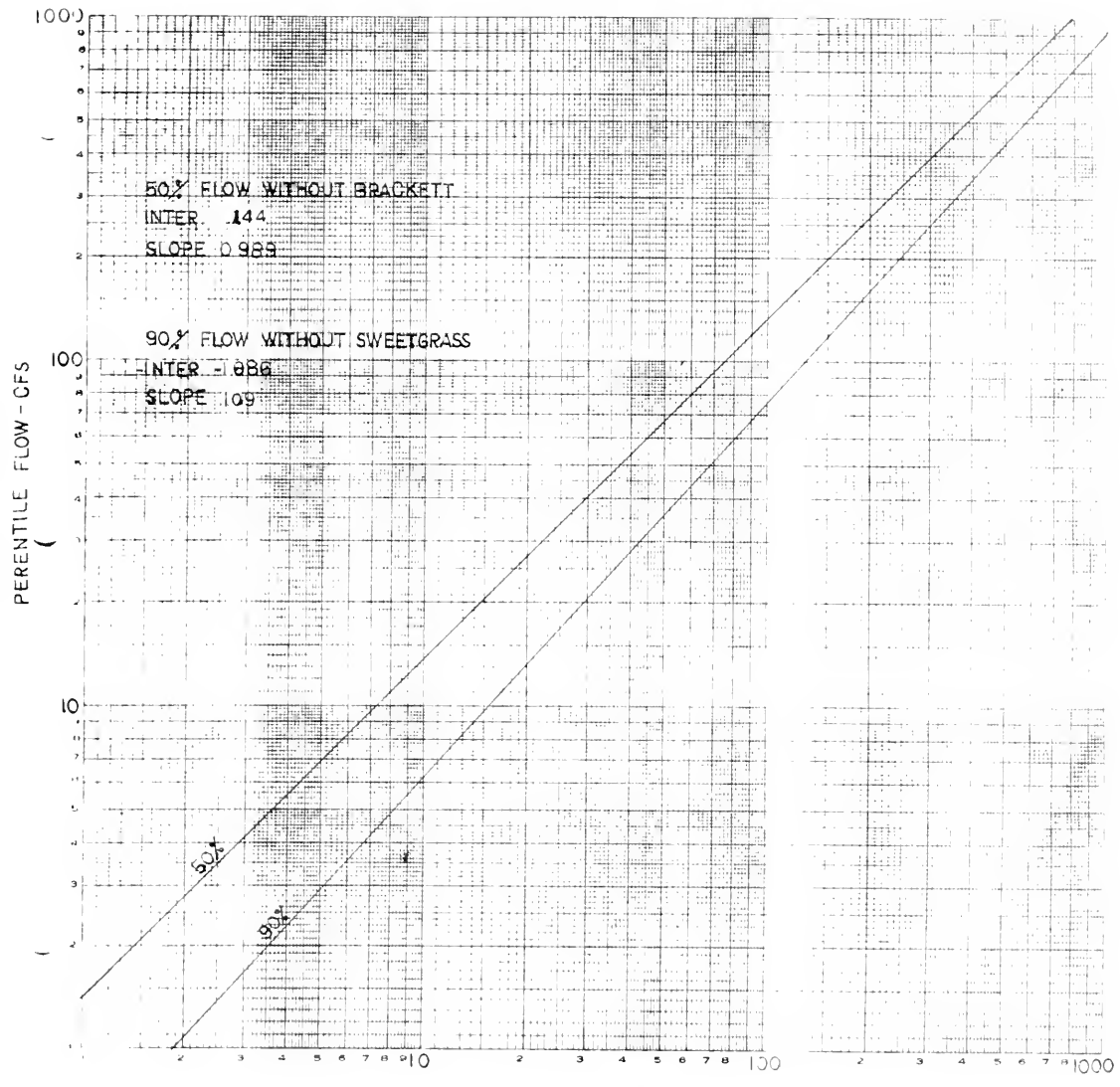


Figure 6 PERCENTILE FLOW VERSUS MEAN FLOW FOR MARCH 1957

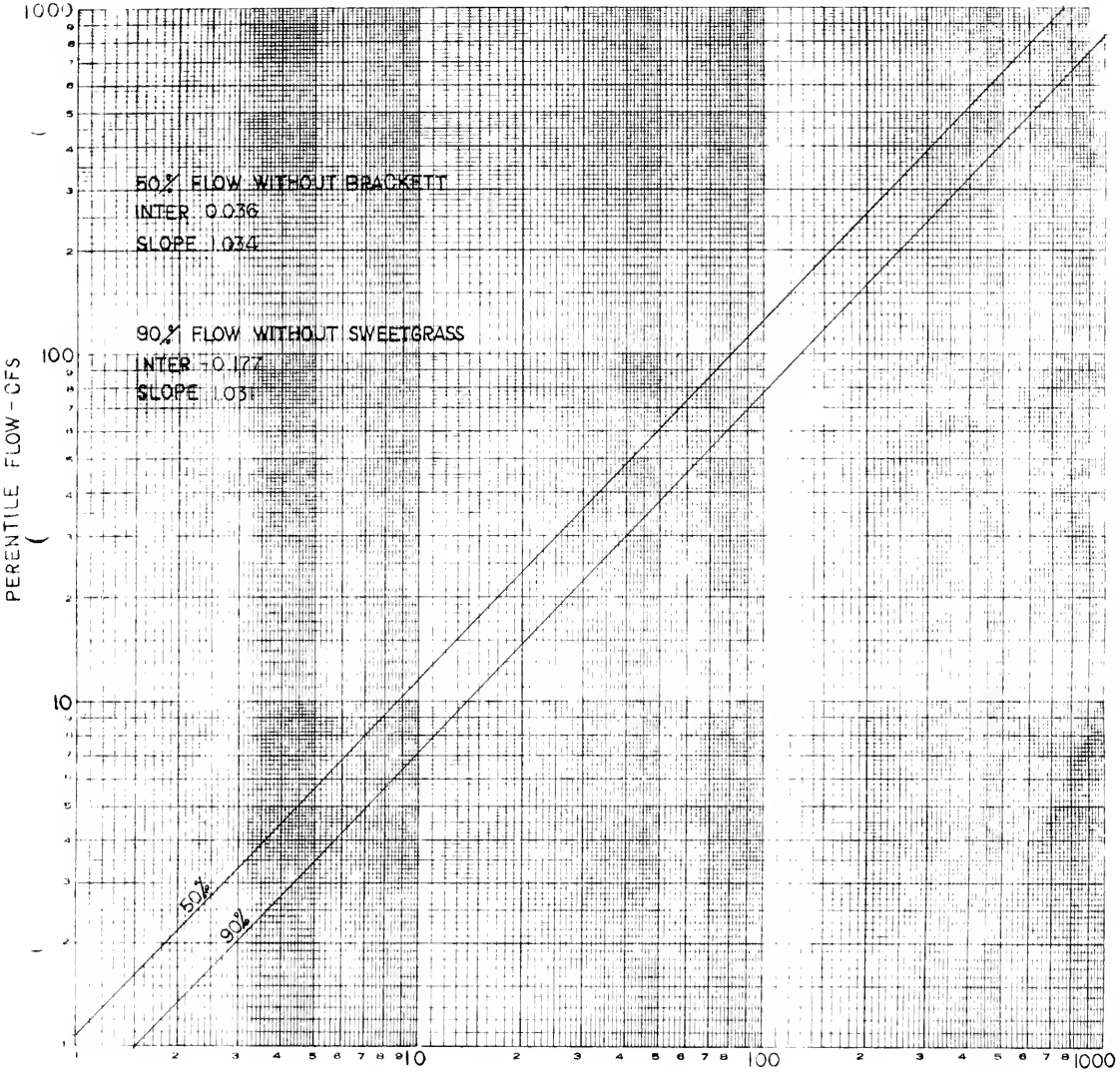


Figure 7 PERCENTILE FLOW VERSUS MEAN FLOW FOR APRIL 1957

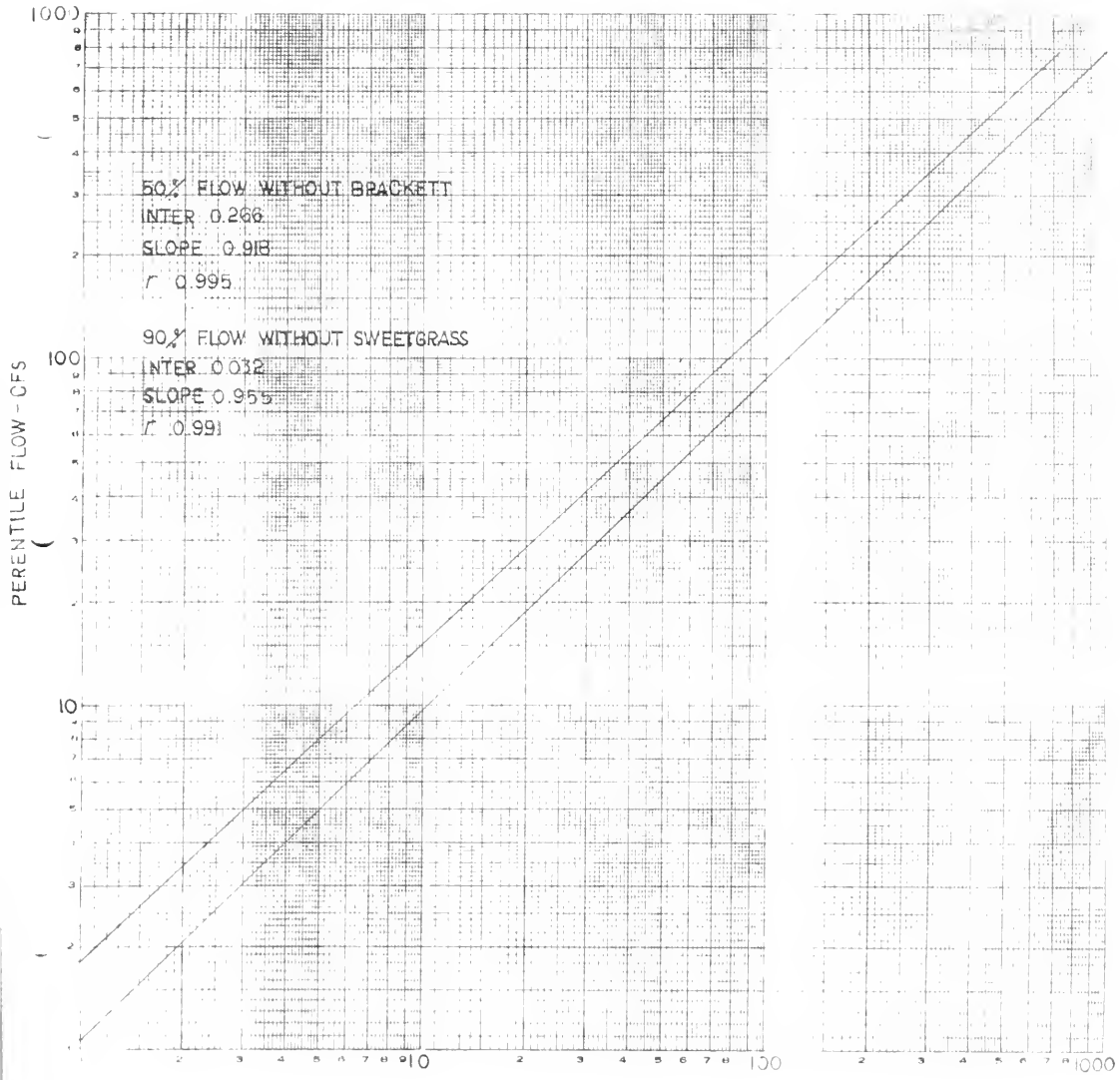


Figure 8 PERCENTILE FLOW VERSUS MEAN FLOW FOR MAY 1957

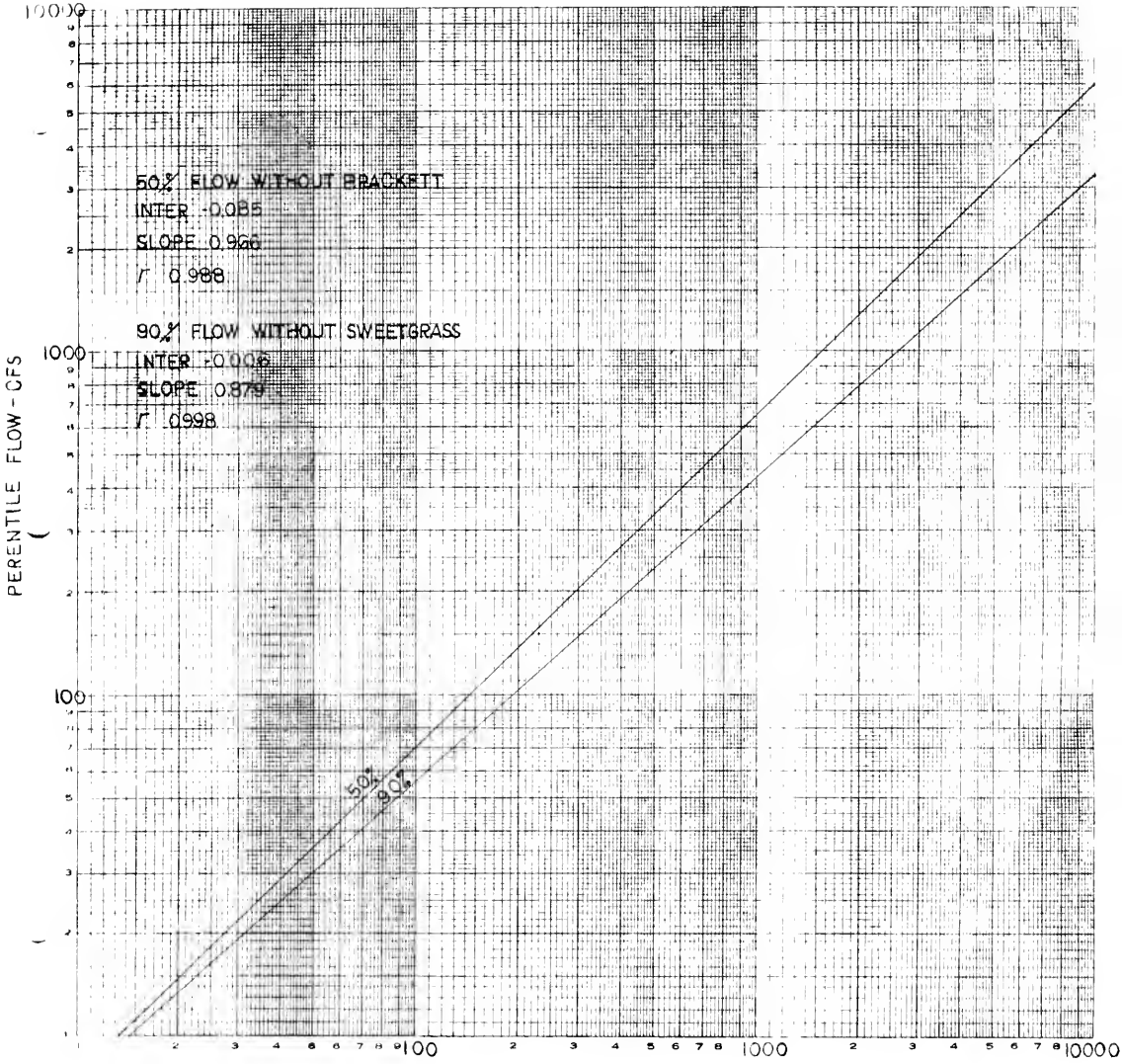


Figure 9 PERCENTILE FLOW VERSUS MEAN FLOW FOR JUNE 1957

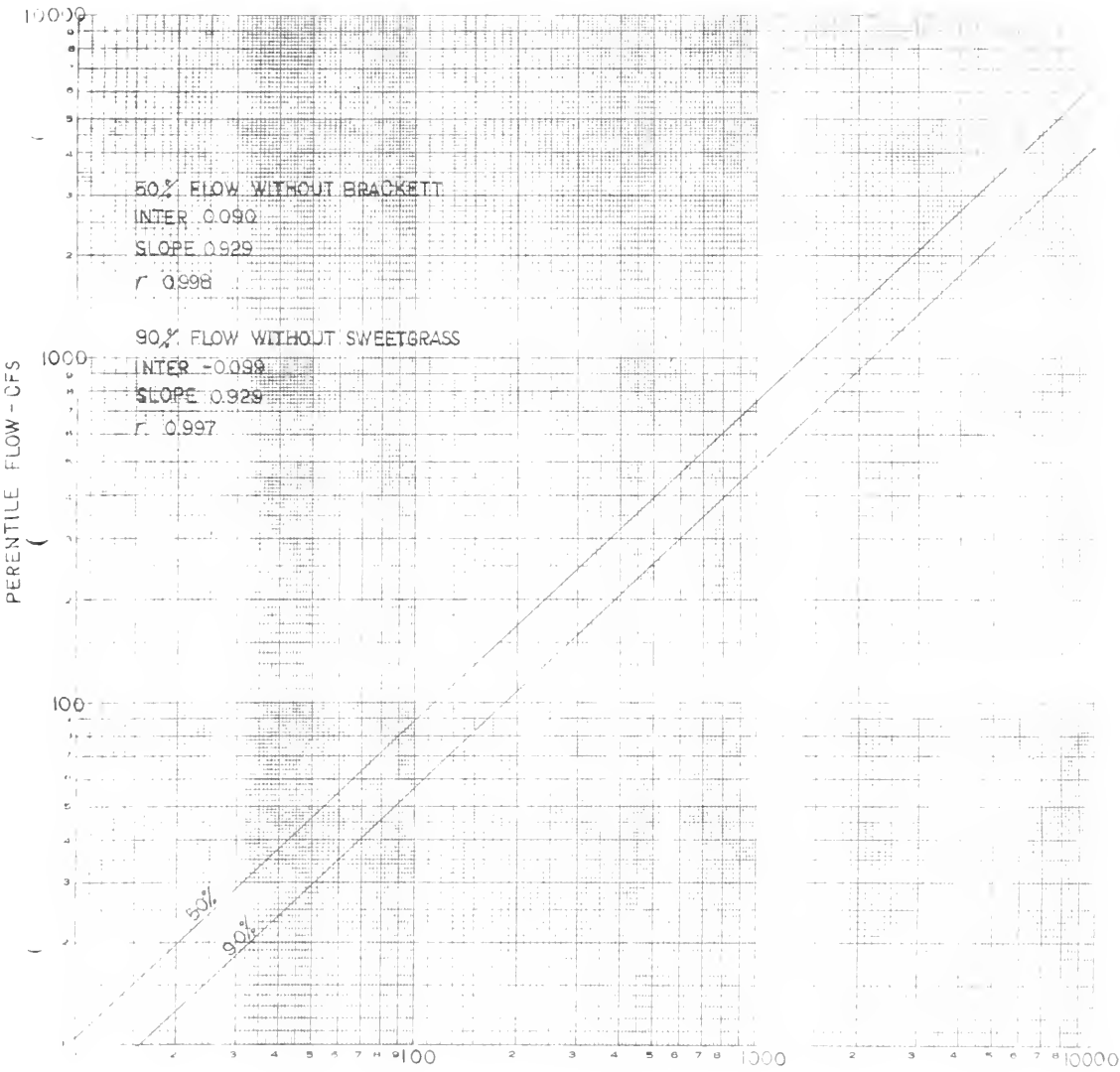


Figure 10 PERCENTILE FLOW VERSUS MEAN FLOW FOR JULY 1957

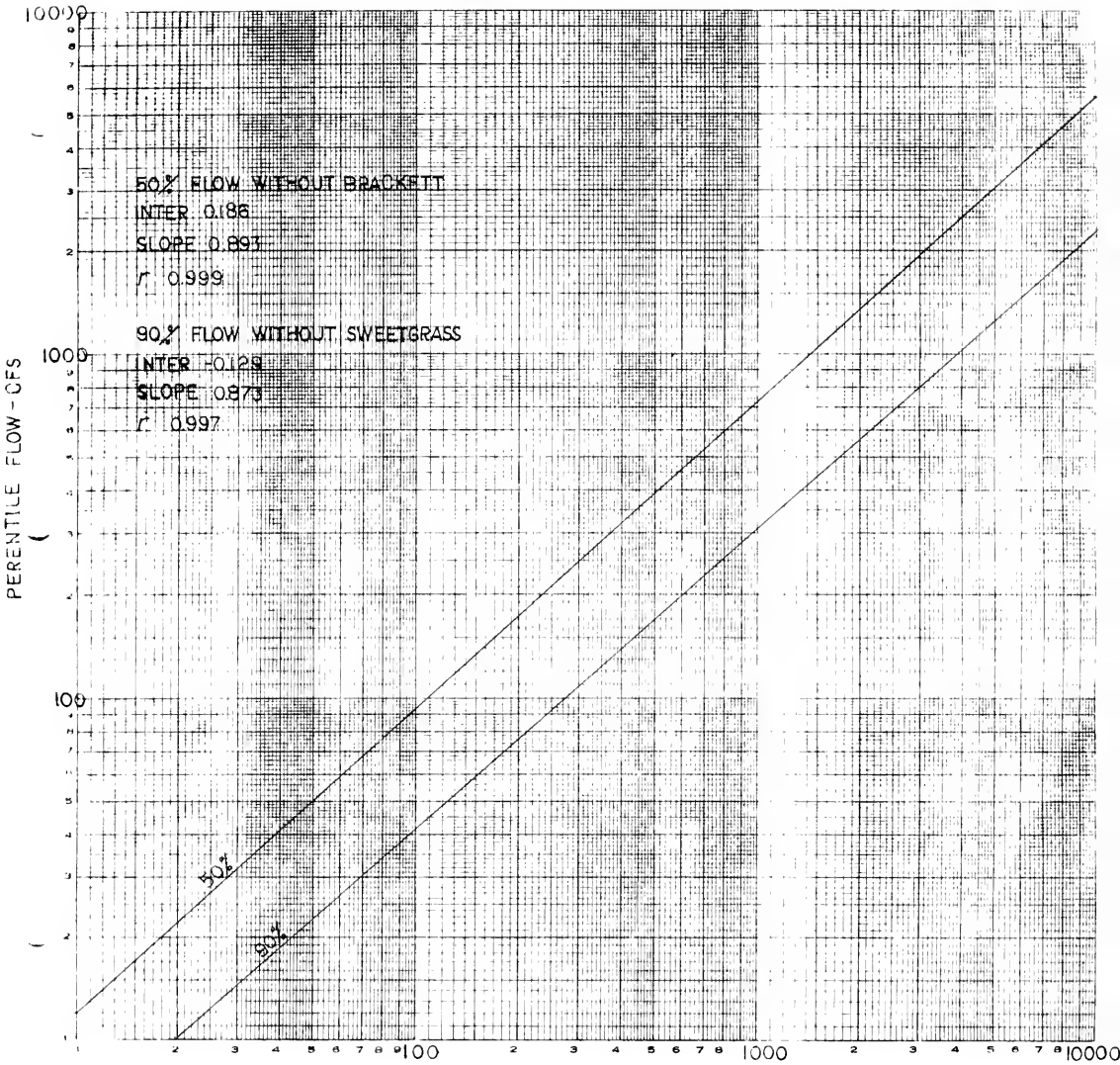


Figure 11 PERCENTILE FLOW VERSUS MEAN FLOW FOR AUGUST 1957

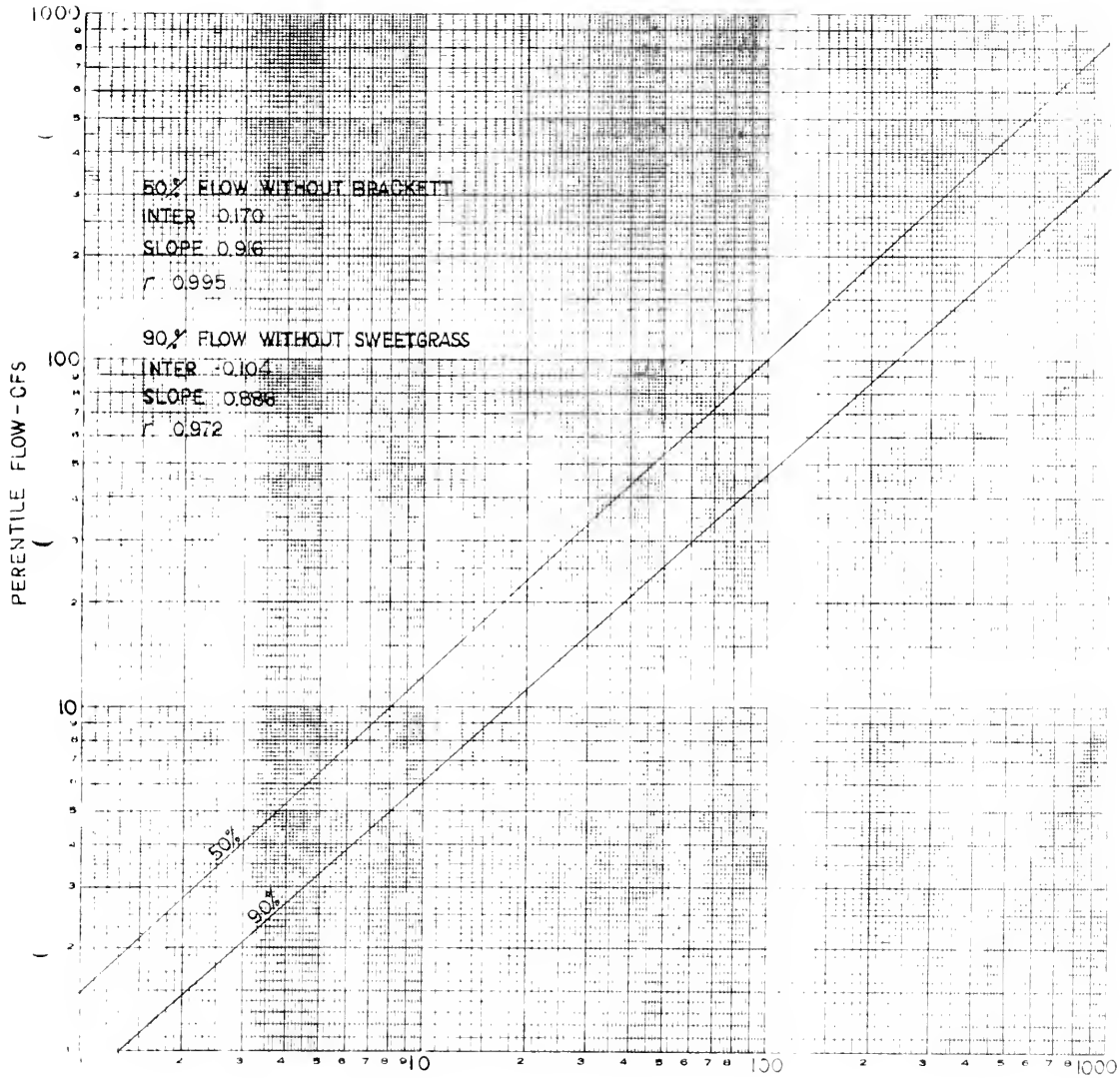
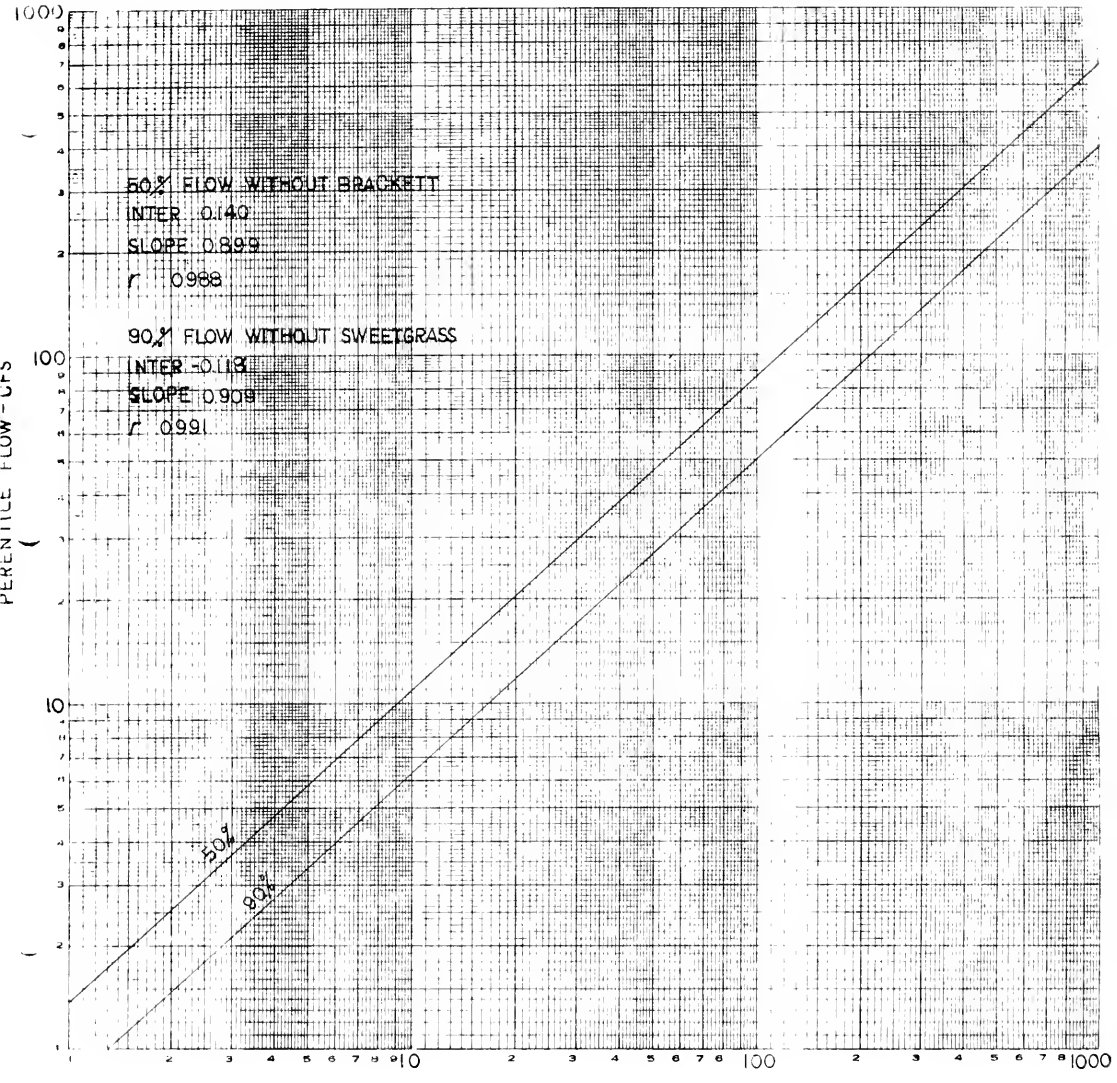


Figure 12 PERCENTILE FLOW VERSUS MEAN FLOW FOR SEPTEMBER 1957



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